J. Field Ornithol., 66(1):81–87

VISIBILITY BIAS OF WATERFOWL BROOD SURVEYS USING HELICOPTERS IN THE GREAT CLAY BELT OF NORTHERN ONTARIO

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Abstract.—Replicate helicopter surveys were employed to examine the efficiency of helicopter-based waterfowl brood surveys in the Great Clay Belt region of northern Ontario during 1990. Waterfowl broods were resighted more often on lake-estuary and lake-shore marshes than on other boreal forest wetland types. Low brood resighting (<40%) on most boreal forest wetland types indicate that a considerable number of broods are missed during helicopter surveys. Differences in resightability were not detected between divers and dabblers. The visibility correcton factor for broods on all wetlands combined was 2.09. Helicopter surveys in the boreal forest should be accompanied by a replicate survey to improve the precision of the waterfowl brood density estimate and establish a visibility correction factor.

VICIOS EN LA VISIBILIDAD DE CAMADAS DE AVES ACUÁTICAS DURANTE MUESTREOS QUE USEN HELICÓPTEROS

Sinopsis.—La replicación de muestreos en helicópteros se usó para evaluar la eficiencia de los muestreos de camadas de aves acuáticas usando helicópteros dentro de la región del gran cinturón de cienos del norte de Ontario, Canadá, durante el 1990. Las camadas de aves acuáticas fueron redetectadas más comunmente en ciénagas de lago-estuario y de lago-costa que en otros tipos de bosques boreales anegados. La baja redetección de camadas (<40%) en la mayoría de los tipos de bosques boreales anegados indica que un considerable número de camadas se ignoran al muestrear desde helicópteros. No se detectaron diferencias en la redetectabilidad entre aves que se zambullen y las que chapotean. El factor de corrección de visibilidad para todas las camadas en todas las áreas anegadas combinadas fué de 2.09. Muestreos en helicópteros en bosques boreales deben acompañarse de muestreos replicados para mejorar la precisión del estimado de densidad de camada de aves acuáticas y para establecer un factor de corrección de visibilidad.

Brood surveys have been a standard means of quantifying waterfowl productivity and habitat use (Dennis and North 1984). Ground searches are often used to estimate brood abundance (Rumble and Flake 1982), although they are labor intensive and generally restricted to accessible habitats. Aerial surveys allow coverage of large, often inaccessible areas, but, they commonly underestimate population densities because animals are missed (Pollock and Kendall 1987). Visibility bias of aerial survey techniques (Caughley 1974, 1977) is usually compensated by comparing aerial and ground counts to establish a correction factor.

The proportion of broods that are observed during a survey depends on several factors, including time of day (Diem and Lu 1960, Ringelman and Flake 1980), wind speed, wave action, light conditions, air temperature (Ringelman and Flake 1980), diel emergence patterns of aquatic insects (Swanson and Sargeant 1972), vegetation (Ringelman and Flake 1980), brood age and species (Ringelman and Flake 1980, Rumble and Flake 1982), helicopter disturbance (Kaminski 1979) and observer experience.

Helicopter surveys have been used to estimate the density of breeding waterfowl pairs in inaccessible habitats, such as the boreal forest, where low numbers of ducks are widely distributed within small wetlands, lakes and streams. Ross (1985) indicated that helicopter surveys of breeding pairs in the boreal forest produce results similar to those of the ground searches. Aerial surveys of waterfowl broods have not been conducted in the boreal forest; however, comparisons of aerial and ground counts in other geographic locations indicate that visibility biases for broods exist and that correction factors must be developed (Ducks Unlimited, unpubl. data). Ground counts in the boreal forest are logistically difficult; therefore it is necessary to develop correction factors for aerial surveys.

Our objective was to determine survey efficiency of helicopter-based brood counts in the Great Clay Belt (GCB) region of northern Ontario and to develop appropriate visibility correction factors.

STUDY AREA AND METHODS

The GCB region of northern Ontario (56,000 km^2) contains a diverse matrix of forested upland and wetland habitats. Black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) are typical conifers, whereas balsam poplar (*Populus balsamifera*) and trembling aspen (*Populus tremuloides*) are primary deciduous trees. Alder (*Alnus rugosa*) and willow (*Salix* spp.) dominate understorey and riparian areas. Although considered part of the Precambrian Shield region, the GCB is overlain by a thick layer of clay (Rowe 1972), and is therefore more fertile than surrounding boreal forest.

As part of an extensive study of waterfowl productivity in the GCB region, the entire area was divided into 140, 10 × 10-km blocks. Each block was subdivided into 2 × 2-km plots. Thirty of these plots were selected in close proximity to airports for logistic efficiency.

Two survey periods were used to account for the phenological difference between early nesting waterfowl species (16–18 Jul. 1990) and late nesting waterfowl species (13–15 Aug. 1990). Surveys were conducted from sunrise to 1130 hours and from 1600 hours to sunset. Within each survey period, replicate surveys were performed 1 or 2 d apart to provide a capture/mark-recapture situation (Seber 1982:59–61). Morning and afternoon surveys were usually reflown during the next morning and afternoon, respectively. On the first survey, observed broods were assumed "captured and marked"; resightings of the same brood during the second survey were assumed "recaptures." The combination of species, size and age class (Gollop and Marshall 1954) was considered the "mark." Broods of the same species, age class (±2 age categories), and size (±2 ducklings) observed on the second survey, on the same wetland, were assumed the same brood. This criteria will provide a conservative estimate of the total number of broods.

Bell 206 Jet Ranger helicopters used in this study were equipped with bubble windows on the rear doors, which improved visibility by allowing the observers to extend their heads outside the body of the aircraft. All wetlands within a plot were surveyed at altitudes as low as 60 m, and at speeds ranging from a hover to 60 km/h. The observer in the front passenger seat navigated and recorded data. The two observers in the rear of the aircraft determined the species, age and size of the broods and conveyed the results to the recorder through an intercom. The pilot did not aid in brood detection.

All information was recorded directly on acetate-covered aerial photographs. If necessary, multiple passes were made over individual wetlands when identification, aging or brood size could not be ascertained on the first pass. Different crews were used for the two replicate surveys to eliminate any experience factor. Each crew member was experienced at identifying and aging broods. Due to the small size of most boreal forest wetlands, total coverage of each wetland was achieved.

Statistical analyses.—Physical characteristics were used to combine seven wetland types into three groups (Table 1). The number of broods seen during the first count, the second count, and on both counts during the July and August surveys combined were applied to the modified Petersen estimator (Chapman 1951) below to estimate brood populations.

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1, \qquad \text{where}$$

$\hat{N}$ = the estimated number of broods in a closed population, n_1 = number of broods seen on the first count ("marked" individuals), n_2 = number of broods seen on the second count, and m_2 = number of "marked" broods seen on the second count.

TABLE 1. Description and number of each wetland type by grouping that were surveyed for waterfowl broods on the Great Clay Belt in northern Ontario, 1990.

Group	Wetland type	Description	n
A	Lake-estuary marsh	Marsh associated at entry point of a stream into a lake.	1
	Lake-shore marsh	Marsh associated with lake shore or bay. No stream associated with the marsh.	2
B	Bog-marsh	Shallow marsh zone extends into bog habitat.	2
	Basin-marsh	Discrete basin marsh with open water and deep and shallow marsh vegetation.	6
C	Beaver pond sequences	Stream flows through the center of marsh zone which is associated with beaver ponds.	8
	Stream marsh	Stream flows through center of marsh zone which is >4 times the width of the open water.	4
	River riparian	Higher order stream, >25% of channel width is open water.	1

The Petersen estimate procedure assumes that the population is closed; i.e., no immigration or emigration. We believe this assumption was valid due to the short duration between surveys. Also, each brood was assumed to have the same opportunity of being sighted within a wetland type.

A 95% confidence interval (CI) for the population estimate was calculated (Seber 1982:59–64) as

$$\hat{N} \pm 1.96\sqrt{\hat{v}}, \text{ where}$$

$\hat{v}$ = estimate of the variance of N

$$\hat{v} = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}.$$

A visibility correction factor (VCF) was calculated for total broods in all wetlands combined, for each wetland grouping, and for dabblers and divers separately for all wetland groupings combined. VCF was determined by dividing the estimated brood population by the number of broods seen during the first count.

Chi-squared contingency tests were employed to determine if brood resightability differed between wetland grouping A, B and C or between dabblers and divers. Tests were considered significant at $\alpha = 0.05$.

RESULTS

A total of 24 wetlands comprising seven wetland types were located on the study plots. Broods of 10 different waterfowl species were identified. Ring-necked Duck (*Aythya collaris*) (36%), Common Goldeneye (*Bucephala clangula*) (16%), Mallard (*Anas platyrhynchos*) (12%), American Black Duck (*A. rubripes*) (10%) and Blue-winged Teal (*A. discors*) (10%) made up the majority of the broods observed. American Wigeon (*Anas*

TABLE 2. Number of waterfowl broods observed on the first (n_1) and second (n_2) survey, on both surveys (m_2), total number of different broods observed, a Petersen Estimate ($\hat{N}$) of population size, 95% Confidence Interval (95% CI) on the population size, and Visibility Correction Factor (VCF) for brood surveys on the Great Clay Belt in northern Ontario, July and August 1990.

Wetland grouping	# Wetlands/ grouping	n_1	n_2	m_2	Total observed	$\hat{N}$	95% CI	VCF
A	3	9	15	9	15	15.0	13.2, 16.8	1.67
B	8	7	6	2	11	17.7	10.3, 25.0	2.52
C	13	15	15	6	24	35.6	21.3, 49.8	2.37
All wetlands	24	31	36	17	50	64.8	50.8, 78.8	2.09

americana), Green-winged Teal (*A. crecca*), Wood Duck (*Aix sponsa*), Lesser Scaup (*Aythya affinis*) and Hooded Merganser (*Lophodytes cucullatus*) were present at low densities (combined 16%).

On all wetlands a total of 31 and 36 broods were observed during the first and second count, respectively (Table 2). Of the 67 broods seen, 17 were observed during both surveys, yielding 50 different brood observations. Of the broods observed on the first survey, 55% were resighted during the second survey. The number of broods on each wetland type are as follows: lake-estuary marsh (11), lake-shore marsh (4), bog marsh (5), basin marsh (6), beaver pond sequences (19), stream marsh (4) and river riparian (1).

Differences in resightability were detected between wetland grouping A and B ($\chi^2 = 6.32$, df = 1, $P = 0.012$) and A and C ($\chi^2 = 6.27$, df = 1, $P = 0.012$) for all species of broods. Of the broods observed during the first survey on Group A, B and C, 100, 29 and 40% were resighted during the second survey, respectively. Brood population estimates, 95% CI and VCFs for each wetland grouping are shown in Table 2.

On all wetland groupings combined, dabblers and dives accounted for 44 and 56% of the total broods observed, respectively. No differences ($\chi^2 = 1.42$, df = 1, $P = 0.233$) in resightability were detected between dabblers and divers on all wetland groupings combined. Differences between divers and dabblers within wetland groupings were not assessed because sample sizes were too small to allow appropriate analyses. Of the dabblers and divers observed on the first survey, 39 and 67% were resighted during the second survey, respectively. VCFs, population estimates and 95% CI for dabblers and divers on the combined wetland groupings are presented in Table 3.

DISCUSSION

Resightability did not differ between divers and dabblers indicating that the behavioral differences between the groups did not result in sighting biases during our surveys. In general, our study indicated that broods may be less visible on boreal forest wetland types than on wetlands in

TABLE 3. Number of waterfowl broods observed on the first (n_1) and second (n_2) survey, on both surveys (m_2), total number of different broods observed, Petersen Estimate ($\hat{N}$) of population size, 95% Confidence Interval (95% CI), and Visibility Correction Factor (VCF) for brood surveys conducted on the Great Clay Belt in northern Ontario, July and August 1990.

Waterfowl grouping	n_1	n_2	m_2	Total observed	$\hat{N}$	95% CI	VCF
Dabblers	13	14	5	22	34.0	18.8, 49.2	2.62
Divers	18	22	12	28	32.6	26.1, 39.1	1.81

other regions. Aerial and ground surveys conducted by Ducks Unlimited Canada (unpubl. data) in Manitoba and New Brunswick wetlands indicated that aerial observers see approximately 70% of the estimated number of broods yielding a lower visibility correction factor (1.43) than was calculated for our boreal forest surveys (2.09).

Waterfowl broods were more visible on lake-estuary and lake-shore marshes during helicopter surveys than on the other wetland groupings. Low resighting on wetland groupings B and C indicate that a considerable number of broods present on these wetland types were not visible during our helicopter surveys. Lower resightability may be due to the extensive emergent vegetation zones and forested shoreline that exist on these wetlands. Broods can quickly move to cover when threatened and may be able to conceal themselves more readily on these wetland types than on the larger, more open, lake-shore and lake-estuary marshes.

Although the results of this study indicate that waterfowl brood visibility was low during helicopter surveys on most boreal forest wetland types, this is currently the only technique that is logistically and economically feasible over this type of terrain. Helicopter surveys can be used in the boreal forest to establish waterfowl brood density indices; however, replicate helicopter surveys should be employed to improve the precision of the density index and obtain a visibility correction factor.

To maximize survey results, it is important to survey when broods are most active and weather conditions are optimal. We recommend that surveys be conducted during the periods of peak brood activity (early morning) and on clear days when wind velocity is low to avoid wave action that makes it difficult to detect wave patterns created by broods. Brood movement along streams may affect brood resightability and should be considered when designing an aerial survey. Unfortunately the extent of brood movement during our study was unknown. Brood age is also an important consideration. Older broods may be easier to detect than younger broods thereby introducing a bias to the results. In our study, the number of broods available within each age class was too small to facilitate an analyses between brood age classes. Observer experience is another important factor that can affect survey results and should be considered when designing aerial brood surveys.

ACKNOWLEDGMENTS

Financial support was provided by Ducks Unlimited Canada, Ontario Ministry of Natural Resources through the Northeast Science and Technology Unit, Wildlife Habitat Canada, and the Canadian Wildlife Service. Field assistance was provided by J. Boos, B. Watt, D. Fillman, S. Konrad and J. Leafloor. N. Arnason provided guidance during the statistical analyses. H. Murkin reviewed earlier drafts of the manuscript.

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Received 31 Dec. 1993; accepted 12 Apr. 1994.